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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04R 3/00

A1

(11) International Publication Number: WO 97/03536

(43) International Publication Date: 30 January 1997 (30.01.97)

(21) International Application Number: PCT/GB96/01622

(22) International Filing Date: 8 July 1996 (08.07.96)

(30) Priority Data:
9513894.7 ; 7 July 1995 (07.07.95) GB

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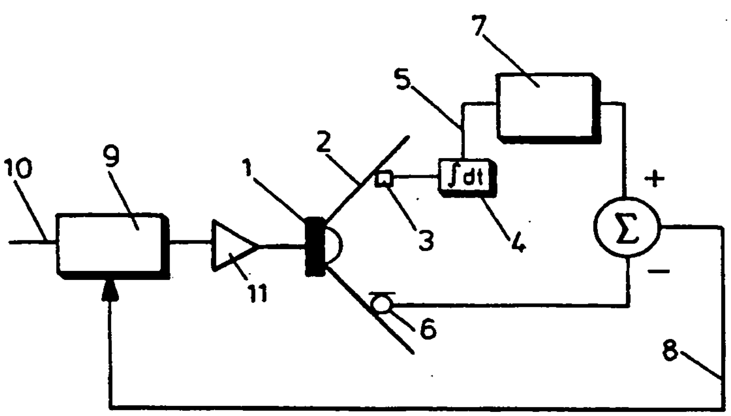
(81) Designated States: AL, AM, AT, AU, AZ, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: LOUDSPEAKER CIRCUIT WITH MEANS FOR MONITORING THE PRESSURE AT THE SPEAKER DIAPHRAGM, MEANS FOR MONITORING THE VELOCITY OF THE SPEAKER DIAPHRAGM AND A FEEDBACK CIRCUIT



(57) Abstract

The present invention relates to a loudspeaker circuit the performance of which can be adapted to the acoustics of the space in which it is placed. The loudspeaker circuit comprises a speaker (1), an input circuit (11) for applying a drive signal to the speaker, first means (6), e.g. a microphone, for monitoring the pressure at the speaker diaphragm (2), second means (3, 4), e.g. an accelerometer, for monitoring the velocity of the speaker diaphragm and third means (7), e.g. a filter, for defining a desired relationship between the monitored pressure and velocity. The difference between the desired relationship and actual relationship between the monitored pressure and velocity is reduced by a feedback circuit (9) driving the input circuit (11). The third means effectively multiplies the monitored velocity by a desired impedance value and a value representing the inter-relation between the output of the first means (6) and the drive signals applied to the loudspeaker.

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LOUDSPEAKER CIRCUIT WITH MEANS FOR MONITORING THE PRESSURE AT THE SPEAKER DIAPHRAGM, MEANS FOR MONITORING THE VELOCITY OF THE SPEAKER DIAPHRAGM AND A FEEDBACK CIRCUIT

The present invention relates to a loudspeaker circuit, and in particular to a loudspeaker circuit the performance of which can be adapted to the acoustics of the space in which it is placed.

It is known to discriminate between pressure components in an acoustic field generated by a loudspeaker from components coming from external sources. This is achieved by measuring the total pressure at the loudspeaker and subtracting from that measurement a value derived from the drive voltage applied to the loudspeaker and representing the pressure which that drive voltage could be expected to produce in the absence of any external pressure sources. This approach has been adopted for example to enable automatic volume control to compensate for variations in background noise. The loudspeaker is therefore responsive to externally generated changes in the acoustic field but in essence the pressure measurement made at the surface of the speaker is simply a convenient indicator of the total pressure which is processed to provide a measurement of the background noise.

It is also known to drive a speaker so as to absorb acoustic energy from an acoustic field in which it is immersed. In the known arrangements, a microphone is used to detect noise components which are to be suppressed, and the loudspeaker is driven accordingly. Such arrangements operate in a different manner from but are equivalent to systems which generate "anti-noise" so as to reduce unwanted noise by destructive interference between the unwanted noise and an "anti-noise" signal.

It is also known to monitor the movement of the diaphragm of a loudspeaker for example by mounting a capacitor on a moving part of the loudspeaker and monitoring variations in current due to capacitance changes. The monitored currents are converted into a proportional voltage which is applied as a negative feedback signal to the loudspeaker amplifier. This circuit in essence corrects the relationship between a drive signal applied to a loudspeaker and the desired response of that loudspeaker to a particular drive signal.

Thus it is known to monitor either the pressure at or the displacement of a speaker diaphragm with a view to generating a feedback signal that is used to modify the drive to the loudspeaker. It has not previously been proposed however to monitor both the pressure at a loudspeaker and the loudspeaker displacement with a view to developing a related feedback signal.

According to the present invention, there is provided a loudspeaker circuit comprising a speaker, an input circuit for applying a drive signal to the speaker, means for monitoring the pressure at the speaker, means for monitoring the velocity of the speaker, means defining a desired relationship between the monitored pressure and velocity, and a feedback circuit responsive to the monitored pressure and velocity and connected to the input circuit, the feedback circuit driving the input circuit to reduce the difference between the desired relationship and the actual relationship between the monitored pressure and velocity.

The acoustic input impedance of a loudspeaker may be considered as the ratio of the total acoustic pressure at the loudspeaker diaphragm surface to the diaphragm

velocity. In accordance with the invention, the acoustic input impedance may be forced to assume particular values so as to cause the loudspeaker to absorb acoustic energy from the surrounding sound field. In addition, in accordance with the present invention the source impedance of a loudspeaker may be controlled by forcing the acoustic input impedance to assume predetermined values. Accordingly, the invention enables the coupling between a loudspeaker and its environment to be modified.

The desired relationship between the monitored pressure and velocity may be selected such that the loudspeaker operates with a predetermined acoustic input impedance. Alternatively, or additionally, the desired relationship may represent a predetermined source impedance.

An embodiment of the present invention will now be described, by way of example, with reference to the accompanying drawing.

The drawing illustrates a loudspeaker circuit comprising a loudspeaker 1 having a diaphragm 2. A miniature accelerometer 3 is attached on the diaphragm and connected to an integrator 4 the output 5 of which represents the instantaneous velocity of the speaker diaphragm. A microphone 6 is also attached to the speaker diaphragm 2, its output representing the total pressure at the surface of the diaphragm.

The output 5 of the integrator is applied to a filter 7 which represents the product of the response of the microphone 6 and a desired acoustic impedance. The filter 7 effectively multiplies the monitored velocity by a desired acoustic impedance value and a value representing the manner in which the output of the microphone 6 is

inter-related to signals applied to the loudspeaker 1. The output of the microphone 6 is subtracted from the output of the filter 7 to generate a signal 8 which represents the difference between the monitored total pressure and the pressure which would be present if the acoustic impedance corresponded to the desired acoustic impedance. The signal 8 is applied to a filter 9 to which an input signal 10 is applied in input signal 10 representing the sound to be produced. The filter 9 modifies the input signal 10 which is applied to an amplifier 11 which drives the coils of the speaker 1.

The acoustic input impedance of a loudspeaker is the ratio of the total acoustic pressure at the loudspeaker diaphragm surface and the diaphragm velocity. Thus:

$$P = VA$$

Where P equals the pressure monitored by microphone 6

V is the velocity as monitored by the accelerometer 3 and integrator 4

A is the desired acoustic impedance.

The output of the filter 7 will be identical to the output of the pressure transducer 6 if the acoustic input impedance of the device is the same as that predetermined by the filter 7. If not, the pressure error signal applied to the filter 9 will cause the loudspeaker to be driven in such a manner that the actual acoustic input impedance is driven towards the desired acoustic input impedance.

The arrangement described with reference to the accompanying drawing will operate to absorb acoustic energy from the sound field. In some applications the loudspeaker can both generate sound and simultaneously control the ratio of the components of pressure at the diaphragm due to sources other than the loudspeaker

and the diaphragm velocity. In such a configuration the loudspeaker both produces sound and presents a defined impedance to externally generated sound. Sound generated by the loudspeaker can be distinguished from sound from external sources by using the known technique of comparing the total pressure monitored by the microphone 6 with the pressure that the loudspeaker can be expected to produce given the drive signal being applied to that loudspeaker.

The circuit could be configured to provide a predetermined source impedance. When a loudspeaker is driven by an applied voltage the response of the loudspeaker is determined by the electro-mechanical characteristics of the device and, to a lesser extent, by the acoustics of the space in which the loudspeaker is located. A loudspeaker may be considered as a constant source of acoustic pressure, driving a radiation load presented by the room or other space in which the loudspeaker is located through a series "source impedance". Adopting such a representation of the operation of a loudspeaker, if the source impedance has a very large value then the loudspeaker velocity is not influenced at all by the radiation load and therefore the loudspeaker behaves as a constant velocity source. If the source impedance is zero, the loudspeaker behaves as a constant pressure source. The source impedance can be manipulated using the monitored pressure and velocity signals obtained with the circuit shown in the accompanying drawing. The acoustic input impedance generated for a given input voltage is forced to assume that value which would exist if the loudspeaker had the desired source impedance. Manipulating the source impedance in

this matter enables the low frequency acoustics of the space to be influenced, and enables the coupling between the loudspeaker and its environment to be modified.

Components of the pressure at the loudspeaker surface caused by the signal driving the loudspeaker may be discriminated from those generated by other sources. This can be achieved by measuring the transfer function between the diaphragm velocity and the resulting pressure in an initialization phase (either in the known absence of externally generated sound or using an appropriate test signal with known autocorrelation structure and averaging out the effects of externally generated sound).

When more than one loudspeaker operates in the same space care should be taken to avoid the loudspeakers competing with one another. To achieve this, each loudspeaker may be provide with means for measuring the pressure its motion causes at the microphone of the other loudspeakers during an initialization phase. Once this coupling has been understood, any interaction between the loudspeakers may be electronically cancelled using essentially the same strategy as that employed within the circuit described with reference to the accompanying drawing.

In the described arrangement pressure is detected by an electret microphone glued to the loudspeaker diaphragm. Other pressure monitoring devices could of course be used, and the pressure monitoring devices would not have to be mounted directly on the diaphragm. For example a microphone mounted on a frame immediately in front of the diaphragm would be capable of monitoring the pressure.

In the described arrangement the diaphragm velocity is monitored by an accelerometer mounted directly upon it. It would be possible to detect diaphragm

velocity in other ways however, for example by driving a further loudspeaker coil with the same signal applied to the main loudspeaker, the further loudspeaker coil having a velocity-detecting component secured to it.

The invention could be used as a combined source (loudspeaker) and absorber which produces sound for entertainment or communication in a built space or inside a vehicle whilst simultaneously suppressing unwanted low frequency acoustic sounds and intervening in the low frequency acoustics of the space to improve the quality of the reproduced sound.

An alternative application of the invention is as a combined source / absorber in a reverberation enhancement system in which the existing acoustic modes of the space are suppressed before the reverberation enhancement system adds (through the same actuator as used to implement the absorber function) the artificial reverberation.

Further alternative applications are as a device to control low frequency acoustic modes in built spaces, to improve the acoustics of these spaces; or as a low frequency noise control measure in buildings or machinery enclosures.

CLAIMS

1. A loudspeaker circuit comprising a speaker, an input circuit for applying a drive signal to the speaker, means for monitoring the pressure at the speaker, means for monitoring the velocity of the speaker, means defining a desired relationship between the monitored pressure and velocity, and a feedback circuit responsive to the monitored pressure and velocity and connected to the input circuit. the feedback circuit driving the input circuit to reduce the difference between the desired relationship and the actual relationship between the monitored pressure and velocity.

2. A loudspeaker circuit according to claim 1, wherein the desired relationship represents a predetermined acoustic input impedance.

3. A loudspeaker circuit according to claim 1 or 2, wherein the desired relationship represents a predetermined source impedance.

4. A loudspeaker circuit substantially as hereinbefore described with reference to the accompanying drawing.

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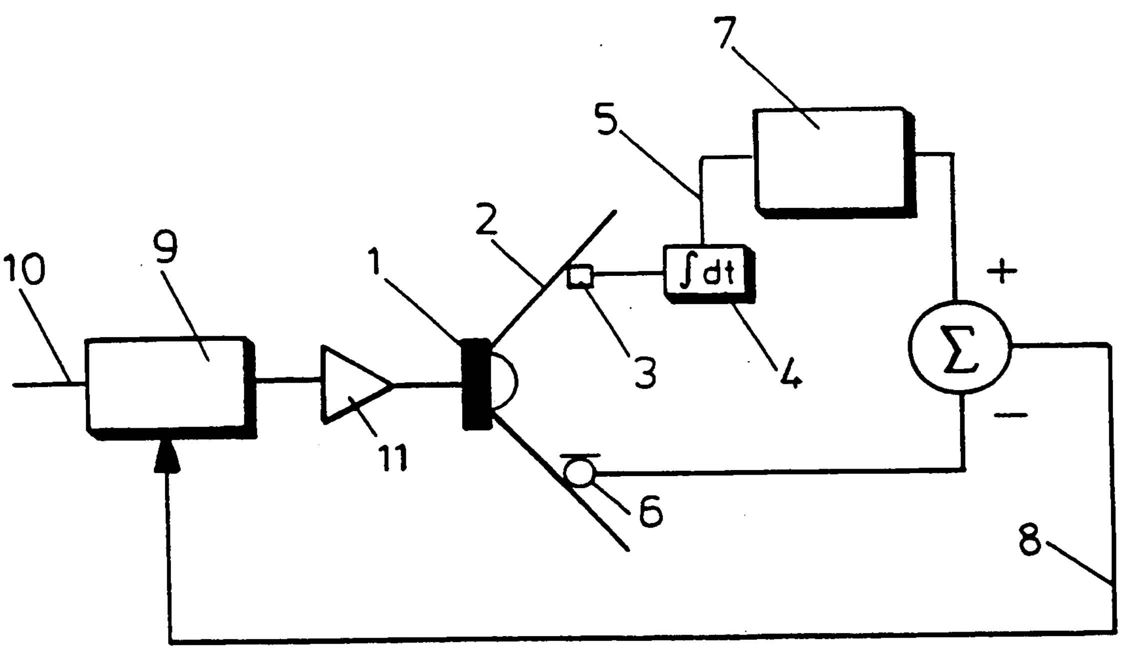

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 96/01622

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04R3/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04R H03G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO,A,84 00274 (B & W LOUDSPEAKERS) 19 January 1984 see page 1, line 3 - page 2, line 4 see page 3, line 10 - page 4, line 18 see page 5, line 1 - page 12, line 19; figures 1-3 ---	1-4
A	EP,A,0 171 065 (MULLER FRIEDRICH) 12 February 1986 see page 6, line 1 - page 8, line 22; figures 1-3 ---	1
A	PATENT ABSTRACTS OF JAPAN vol. 009, no. 004 (E-288), 10 January 1985 & JP,A,59 153398 (MITSUBISHI DENKI KK), 1 September 1984, see abstract -----	1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
26 September 1996	25.10.96

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INTERNATIONAL SEARCH REPORT

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WO-A-8400274	19-01-84	AU-A-	1772783	26-01-84
		EP-A-	0113370	18-07-84
		GB-A,B	2131651	20-06-84
EP-A-0171065	12-02-86	DE-A-	3429147	20-02-86